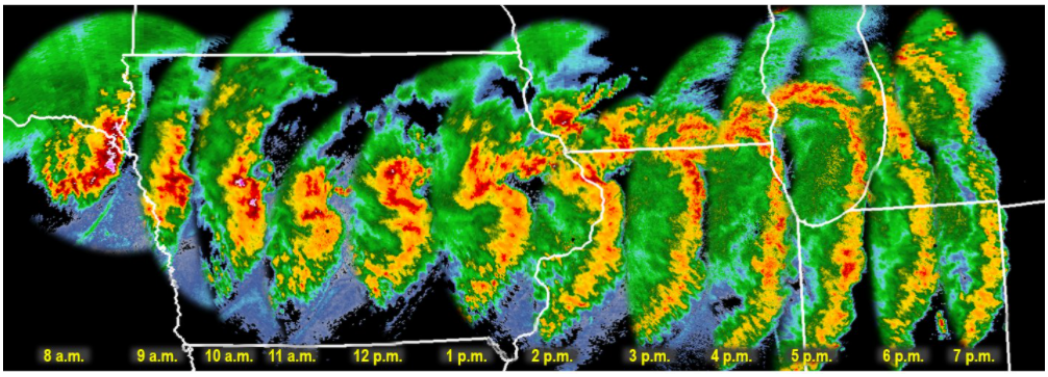
Central Region After-Action Review

August 10th, 2020 Derecho Event



U.S. DEPARTMENT OF COMMERCE

National Oceanic and Atmospheric Administration

National Weather Service, Central Region Headquarters

Kansas City, Missouri

March 10, 2021

1. Event Summary

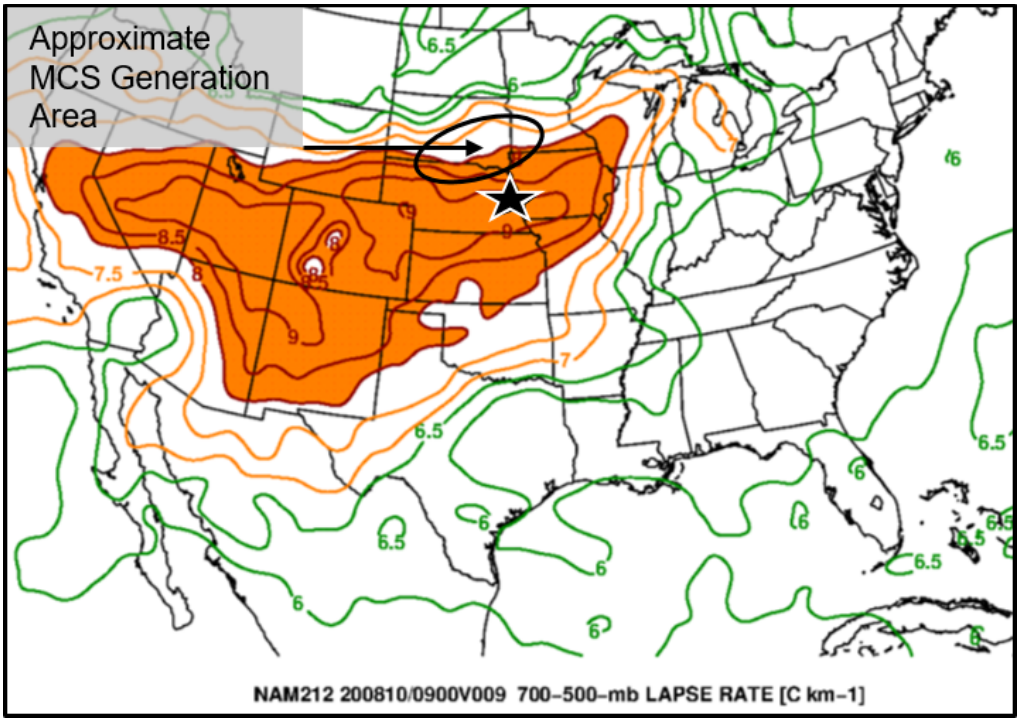
A catastrophic and deadly thunderstorm complex struck portions of the Midwest on 10 August 2020 as a derecho rapidly moved east from eastern Nebraska into the central Great Lakes Region. The Midwest's Corn Belt was particularly hard hit as winds up to 130 mph ravaged portions of central and eastern Iowa. Of particular interest with this system was the duration of severe winds, as many locations in Iowa experienced 70+ mph winds for more than an hour. The end result was catastrophic, as millions of acres of crops were severely damaged or destroyed and countless homes and businesses were damaged. Sadly, 4 fatalities occurred as a direct result of this storm system and numerous injuries were also reported. In addition to widespread crop damage, the system also presented a significant warning challenge as the tornado threat rapidly intensified over portions of northern Illinois to include the greater Chicagoland area. In total, 15 tornadoes were surveyed over northern Illinois and southern Wisconsin, with additional tornadoes also documented across portions of Iowa and northern Indiana. And lastly, the strong winds associated with the derecho also posed a significant threat to mariners and recreational beach goers on Lake Michigan as strong winds led to a heightened meteotsunami threat over southern portions of the lake. Complicating matters for local forecast offices charged with handling this event were ongoing COVID-19 health crisis restrictions which forced all NWS offices to operate with minimal staffing. Furthermore, the predictability of this event was perceived to be low, as several high-resolution models failed to resolve the thunderstorm complex in the overnight hours leading up to the event. As the true nature of this storm complex came into better view, numerous creative and locally-engineered solutions were employed by forecast offices as they navigated through the many challenges associated with an event of this magnitude during a global-health pandemic. At the conclusion of this event, NOAA estimated that the derecho resulted in $7.5B worth of damage, making this the costliest known thunderstorm event in modern U.S. history.

2. Findings

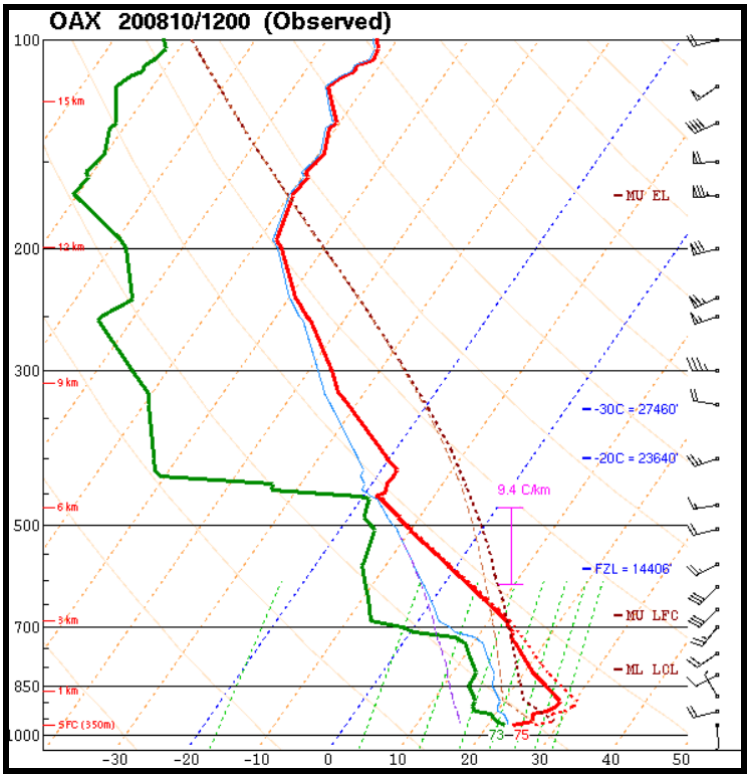
What happened?

a. Event Evolution

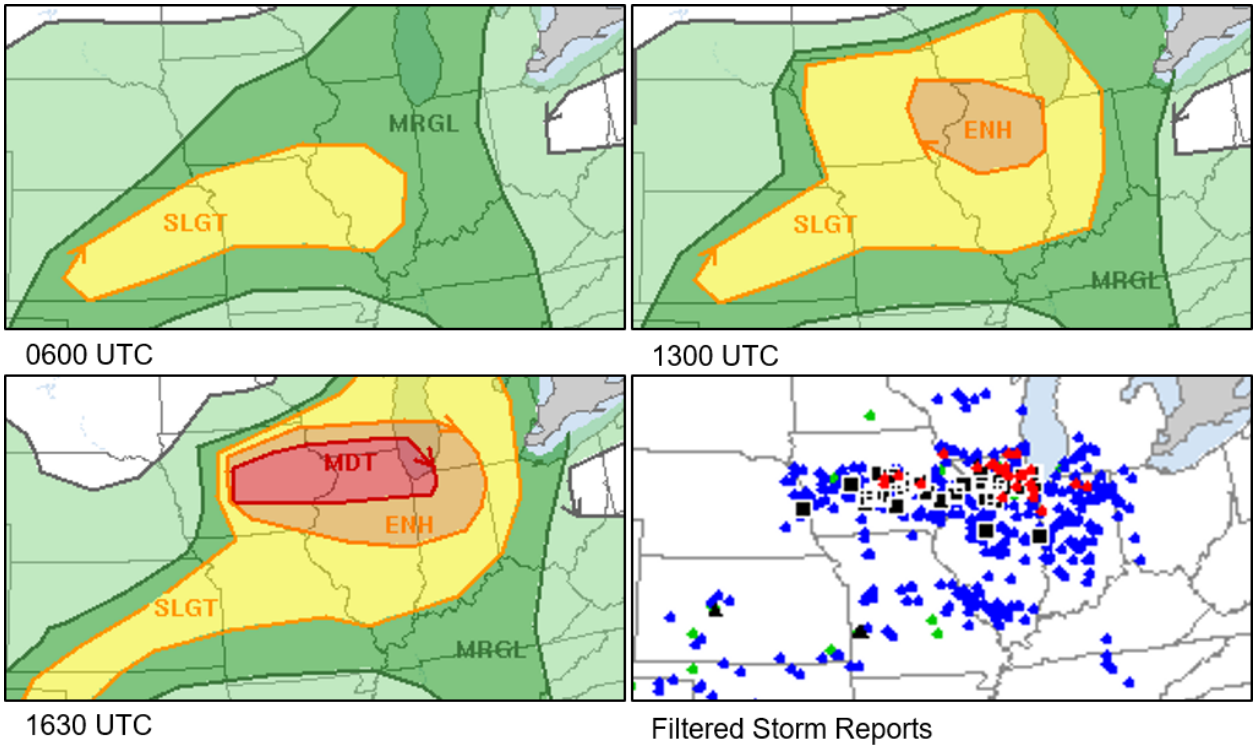
Thunderstorm activity developed over south-central South Dakota during the overnight hours of 10 Aug 2020 in an environment characterized by steep mid-level lapse rates due to the presence of an elevated mixed layer (EML) aloft. This activity appeared to develop along the northern flank of the EML plume as evidenced by the 9-hr 0000 UTC 10 August 2020 12-km NAM mid-level lapse rate forecast below (image courtesy of CIPS; Saint Louis University) in a region of modest 700 hPa moisture convergence ahead of a mid-level shortwave trough that was moving through the northern Plains (not shown).



The 1200 UTC 10 August 2020 Omaha, Nebraska (OAX; approximate location denoted by star in above figure) sounding taken from well within the EML plume shows lapse rates approaching the dry-adiabatic lapse rate (9.8°C km^{-1}) through roughly the 600-450 hPa layer where lapse rates peaked at 9.4°C km^{-1} (below).



With impressive instability in place in an otherwise capped environment, the Storm Prediction Center (SPC) issued a Marginal risk with their 0600 UTC Day 1 convective outlook (below) for portions of the Midwest to include much of Iowa and northern Illinois.



Between the 0600 and 1300 UTC SPC day 1 convective outlooks, convection developed across southeast South Dakota and quickly organized into a forward-propagating MCS over eastern South Dakota and northeast Nebraska. SPC quickly noted the increasing threat and introduced an Enhanced risk over portions of eastern Iowa and northern Illinois with their 1300 UTC day 1 update which was sent earlier than scheduled to provide more advance notice. This was further upgraded to a Moderate risk with the 1630 UTC outlook, which was also sent out early. The Moderate risk included central Iowa, northern Illinois, northwest Indiana, and southern Wisconsin.

b. Rapid evolution of near-storm environment over northern Illinois and southern Wisconsin

As the derecho moved into northern Illinois and southern Wisconsin, the near-storm environment became increasingly favorable for tornadogenesis as winds in the 2-3 km AGL layer increased to 40 kts ahead of the approaching derecho. This increase in low-level wind speed was sampled by VWPs on the WSR-88D and two TDWRs in northern Illinois. Unfortunately, this was not noticed in real time. Moreover, the SPC mesoanalysis page's native 40 km resolution did not capture an increase in 0-3 km Storm-Relative Helicity (SRH) values as a result of the increase in the 2-3 km AGL winds. Realized after the fact, such an increase in winds as sampled on the three VWPs

in northern Illinois, would've likely doubled the Significant Tornado Parameter values across the densely populated area of northern Illinois and southern Wisconsin.

c. Meteotsunami Threat

Internal collaboration between Davenport (DVN) and WFO LOT suggested that the strongest winds associated with the approaching derecho were lasting upwards of 30 minutes in some locations. This combined with the forward speed of the derecho, pressure rises immediately following the line of most intense convection, and known conceptual models of meteotsunamis over southern Lake Michigan, led to an increased concern that a meteotsunami would be possible as the derecho tracked over Lake Michigan. As concern grew, WFO LOT effectively communicated with both the Grand Rapids (GRR) and Northern Indiana (IWX) forecast offices, all three of which issued appropriate Beach Hazard Statements, Special Marine Warnings, and made appropriate and effective contact with core and deep-core partners who would potentially be impacted by this threat. Furthermore, offices communicated these threats over social media, which provided great reach with the marine users and recreational beach goers. Abrupt water level changes of 1-2 ft were recorded at multiple gauges along the south shore of Lake Michigan as a direct result of the derecho moving across southern portions of the lake.

d. Aviation Impacts

On the morning of August 10, the day shift Center Weather Service Unit (CWSU) meteorologist collaborated with the Aviation Weather Center (AWC) on the Traffic Flow Management (TFM) Convective Forecasts (TCF). The CWSU meteorologist asked for an increase in thunderstorm coverage for the Chicago airspace and requested that the graphics be issued as quickly as possible so that they would be available for the CWSUs Pre-Duty Weather Briefing (PDWB). This proactive collaboration ensured that the latest storm timing and trends were available to all operational FAA employees and the TCF helped set the tone for the day and set the FAA Command Center up for success with respect to the management of national air traffic.

Subsequently, timely and well-collaborated convective outlook upgrade discussions between WFOs DVN, LOT and the SPC led to an early notification of Center Weather Service Unit (CWSU) Aurora forecasters that an increase from Marginal risk (Level 1) to Enhanced risk (Level 3) would be forthcoming with the 1300 UTC Day 1 convective outlook update. This and consistent messaging contributed to the continued escalation of preparedness activities for both CWSU and Federal Aviation Administration (FAA) employees. This not only included FAA personnel in the collocated Aurora, Illinois Air Route Traffic Control Center (ARTCC; hereafter referred to as ZAU), but also crosstown FAA personnel at the Chicago Terminal Radar Approach Control Facility (TRACON) and individual airport tower staff. Proactive Ground Delay Programs and Ground Stops were

issued to ensure safe, efficient pre and post storm air travel. A tornado warning was eventually issued for the ZAU facility at 2014 UTC. This prompted ARTCC managers to query the onduty CWSU meteorologist whether the tornado would hit the facility. The CWSU forecaster informed ARTCC management that the tornado would likely not hit the facility and it was decided to move into ARTCC-Alert status (no evacuation) as a precaution.

Enhanced aviation-related IDSS activities were also carried out by WFO LOT, which has TAF-writing responsibilities for both O'Hare (ORD) and Midway (MDW) airports. Consistent ZAU CWSU and WFO LOT verbal briefings to ORD tower as the line approached prompted ORD Tower to proactively prepare for tower evacuation due to forecasted wind speeds with the approaching derecho. Ultimately, a tornado warning was issued which included the ORD airfield and this, along with upstream wind gust observations, resulted in the temporary evacuation of the tower (ATC-Zero). It was also later learned that the TRACON also briefly evacuated when a tornado warning was issued for their location.

What went well?

Finding 1: The coordination/collaboration between many offices, in addition to teleworkers, should be recognized as a massive success for the National Weather Service (NWS). Considering all of the circumstances working against the NWS on this event (reduced staffing in operations due to COVID-19, and a highly uncertain and rapidly evolving high-end severe weather event), the intraoffice coordination can be pinpointed as a significant reason the losses to life, property, and the economy were lower than what probably should have occurred.

There were several prime examples of what NWS collaboration should look like, both presently and in the near-future. First, the coordination between SPC, LOT, and DVN made a significant difference in messaging the morning of this significant event. As a result of their collaboration, meteorologists were able to accurately upgrade convective outlooks to a level in which the public and partners would take notice.

Second, the coordination between WFO LOT and ZAU forecasters resulted in area aviation partners making substantial changes to their operational plans as a result of the updated forecast. The adjustments impacted many aviation partners around not only Chicago but across the country, and included adjustments to arrival rates, ground stops, and a yes/no decision on whether to evacuate the ARTCC facility when a tornado warning was issued. As a result, no aviation incidents were reported in addition to lessening of the economic impact from flight delays and cancellations.

Further, WFOs LOT, IWX, and GRR collaborated on the potential meteotsunami, as well as which product type would most appropriately be used for messaging, to provide users

with a unified product (Beach Hazards Statement) that most accurately conveyed the anticipated threat. Further, DVN, as the upwind CWA, provided a heads-up notification to LOT on the duration of the winds within the derecho, further improving confidence and coordination on the potential meteotsunami. By all WFOs, both upwind and downwind, working together on resolving and messaging this threat, and through coordinating a product while utilizing principles from Hazard Simplification, the public and partners were aware of the incoming storms well in advance of the storms' arrival to prevent any loss of life.

Finally, shift workers in a telework status were used effectively to further information sharing on a potential significant event. Teleworkers were utilized to provide partner calls on the meteotsunami threat, and one teleworker deployed to monitor changes in Lake Michigan lake levels. These actions enhanced information sharing, which only further supports the mission to protect life and property.

Finding 2: A full-office concept was employed at some offices to handle the incredibly challenging workload associated with the derecho. One shining example of full-office concept included the ASA at WFO Des Moines (DMX) being brought in to help triage incoming phone calls. By leveraging the talent of all employees, offices were able to adjust and meet the high workload demands.

Finding 3: Proactive phone calls were made by several offices to provide crucial IDSS to vulnerable populations, including COVID testing facilities. It was reported that these calls were made up to two hours in advance so front-line testing operations could make decisions to close with plenty of lead time. Several testing sites were impacted as a result of the derecho. Overall, the one-to-one IDSS provided to deep-relationship core partners saved lives and reduced property damage. It was also found that offices should ensure clear definitions and procedures, particularly for COVID testing facilities, are being used locally for all IDSS events to prevent any confusion on expectations and to maximize awareness.

Finding 4: Good decisions were made by WFOs with regards to post-event storm surveys. In some instances, it was determined that COVID-19 restrictions would have posed unnecessary risk to NWS personnel because of the contagious nature of COVID and single person vehicle occupancy restrictions. Further, additional safety concerns, such as significant infrastructure damage and downed power lines, posed an undue risk to NWS employees so it was best not to conduct surveys, instead leveraging tools such as social media, information and imagery from emergency managers/responders, and new technologies such as Sentinel satellite data.

Finding 5: Several forecast offices took advantage of high-resolution satellite imagery from MODIS and Sentinel following the event. This information was used to help identify impacted areas to include possible tornado tracks. In some cases, comparing images

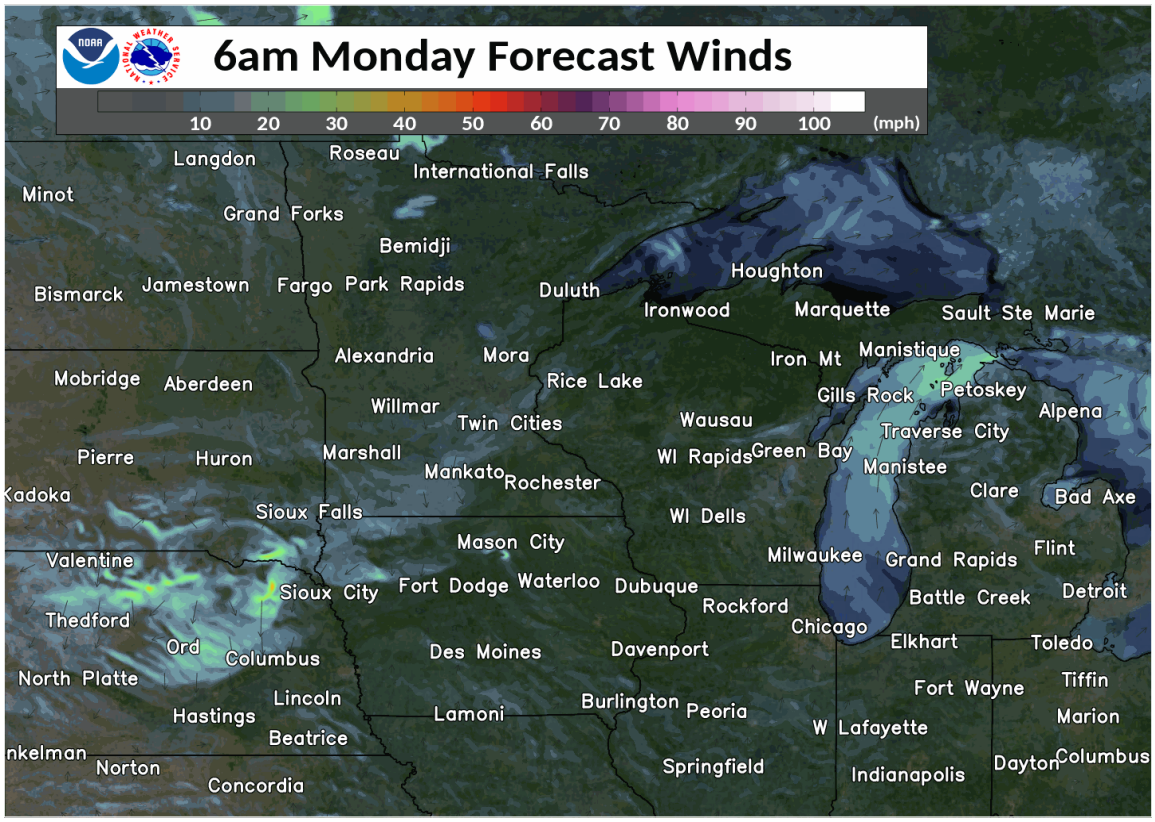
taken before and after the event allowed for adjustments to the starting and ending points of documented tornado tracks. Additionally, nighttime light imagery from the VIIRS satellite also provided guidance on straight-line wind contours.

Finding 6: WFO LOT developed a post-event playbook to adapt staffing and duties during situations such as operations following the derecho. It was reported that this playbook was *"important to help operations fluidly transition to post-event work and ensure an event is seen through in a complete and consistent manner."* WFO LOT was able to meet a significant shift in mission, from the warning and critical IDSS phase to performing tasks such as damage assessment, information gathering/distribution, and any clean-up response activities needing support. This playbook was implemented immediately following the derecho exiting the CWA. As a result, extra staffing was available to begin assisting with immediate needs, blue sky activities were executed on the midnight shift to continue preparing and distributing information, and actions were taken to prepare the next day's storm surveyors and the PIO role with talking points.

What can be improved?

a. Science

1. The overall perception from many indicated this event had low-predictability as several convection-allowing models (CAMs) failed to resolve convection and the overall high-impact nature of the resultant MCS. For example, the SPC HREF ensemble, along with the 0000 and 0600 UTC 3 km NamNest, failed to explicitly forecast a high-impact MCS moving across the upper Mississippi Valley and central Great Lakes regions. Meanwhile, several runs of the HRRR and HRRRx did in fact resolve this thunderstorm complex (see animation below from 0400 UTC HRRR), which did provide increased confidence to forecasters at WFO LOT that a widespread and impactful MCS would be possible later in the day. **Efforts should be made to explore this event from a model predictability standpoint to further understand why some CAMs forecasted system while others did not.**



0400 UTC 10 August 2020 HRRR 10m wind forecast.

2. Early in the event, strong convective winds moved perpendicular to the radar beam in eastern Nebraska and western Iowa. This posed a challenge to warning forecasters as the true radial velocity of the winds, measured by radar, were impacted by an unfavorable viewing angle. Given the challenges such situations pose to a warning forecaster, **a review of known tools and documented radar-observable moments should be conducted annually by forecasters tasked with warning decisions.**

3. The spatial and temporal resolution of available mesoanalysis guidance available to forecast offices remains an issue. For example, the SPC Mesoanalysis page remains mapped at a 40 km resolution and updated hourly, while the native Rapid Refresh (RAP) model, which serves as the baseline for the SPC Mesoanalysis page, has a native 13 km resolution. (Note: SPC has tested higher resolution versions of the Mesoanalysis Page including a 20 km version, but did not identify impactful differences between the analyses.) Joint SPC-EMC-NSSL-GSL tests and evaluations, as part of the Hazardous Weather Testbed Spring Forecast Experiment, indicate that forthcoming high resolution 3D RTMA holds great promise as a mesoanalysis tool, but it is still a couple of years (FY23 or FY24) from being operational. With a strong emphasis now being placed on mesoanalysis in the operational forecasting environment, **efforts should be made to secure higher resolution datasets to improve mesoanalysis efforts for all convective situations.**

4. The rapidly increasing tornado threat was not immediately identified as the derecho moved into northern Illinois as winds in the 0-2 and 0-3 km layer increased, which led to much higher effective storm-relative helicity values than indicated by most available mesoanalysis tools. This increase in low-level winds was captured by VAD wind profiles at KLOT, TORD, and TMDW and it is important to recognize that such changes can happen on very short times scales and that coarsely-resolved mesoanalysis graphics may fail to capture such occurrences. **It is imperative for forecasters to have awareness of tools that allow them to make on-the-fly hodograph adjustments based on available VWP output from local radars.** (See Action 7)

5. Mesoanalysis was utilized and prioritized unevenly from WFO to WFO and in one situation, the mesoanalyst was forced to become a warning forecaster when the tornado threat increased in the affected CWA. This event and the key role that subtle environmental changes played in the severe weather threat and storm morphology **underscores the importance of increased emphasis on mesoanalysis, completion of the Mesoscale Environmental Assessment training, and potential benefits of the Central Region Remote Mesoanalyst Support Program.**

6. This event highlighted the challenges of anticipating the development, magnitude and evolution of high-end QLCSs. Research has identified the difficulty of recognizing/communicating significant hazards (i.e. wind driven hail, 70+ mph straight line winds, etc) in WFO-issued warning products. It is recommended that consideration be given to a team (e.g., Damaging Wind Improvement Project) to investigate improved recognition of supportive environments, identification of precursors when convection is transitioning to widespread damaging winds, best practices for communicating the increasing threat to downstream partners, documentation of radar-derived confidence builders for more effective and realistic polygon threat selections and placement. (See Actions 1 and 6)

b. Services

1. A few impacted offices noted disruptions or delays in operations as a result of short staffing. One contributor to this issue appears to be an overreliance on SPC convective outlooks to drive WFO staffing decisions. As previously stated, model guidance failed to capture the evolution of the event ahead of time, which made for a very difficult forecast for SPC and the impacted WFOs. Improved model guidance would have likely changed this outcome. Still, alternative staffing considerations could have reduced stress on the workforce, and enabled more opportunities for mission-critical IDSS, and distribution of important information to partners and the public. As a result, it is recommended that **WFOs consider SPC outlooks as one of many inputs to staffing decisions within the Trigger Charts and Playbooks. Training, developed at a regional or national level, should be provided on selecting office tempos/playbooks based on**

anticipated weather concerns, as well-managing staffing based on the tempo selected.

2. Interoffice communication and collaboration were very effective in some aspects of the event, but in other areas inconsistent messaging was found. It is important that all involved with forecast operations be in close contact with each other for outlook and messaging coordination purposes. **WFOs across CR already coordinate well on the forecast grids, but it would be beneficial to expand the focus to ensure messaging is consistent to local, state, regional, and national partners. Further, message coordination methods should be improved, especially in times when a rapid escalation in messaging is required such as was the case during this event.** Methods such as collaboration calls/virtual meetings, such as those with WPC, CR ROC, and WFOs ahead of winter weather events, should be evaluated for feasibility and usefulness.

3. While overall statistics were excellent for this event, there is a need for training on severe thunderstorm warning and polygon methodologies for QLCS, derecho, and longer-lived wind events to ensure a common approach between offices. Such training should focus on polygonology techniques such as longer duration warnings, limiting the number of counties within polygons, using county-based polygons to reduce the number of polygons covering a county during a single event, utilizing new polygons to better highlight high-end threats, and planning future warnings. In addition, **the pending implementation of the Wireless Emergency Alerts (WEA) for high-end severe thunderstorm warnings will add additional considerations and training requirements to the warning process.** (See Action 1)

4. Several WFOs with this event reported problems in conducting post-event operations, or all the duties and non-routine responsibilities that occur immediately following significant weather events. These duties include, but are not limited to, warning verification, monitoring and responding on social media, conducting storm surveys, providing information and additional support to government agencies and the media, coordinating with other NWS offices (ex. State Liaison offices, CR ROC), etc. At times, post-event operations reach a tempo similar to that of other high-impact weather playbooks. **It is recommended that CRH and WFOs build Post-Event Playbooks to help define roles, manage responsibilities, and coordinate appropriate staffing levels.** (See Action 8)

5. While the use of employees in telework status was implemented successfully in many cases, several issues were noted, particularly when teleworkers lost internet connectivity due to power outages. Further, offices mentioned feeling the workload was overwhelming at times, or that services were degraded due to a lack of staffing. Finally, mesoanalysts were repurposed to directly support warning operations (i.e. issuing warnings), leaving offices without a dedicated mesoanalyst during the event. In response

to the COVID-19 pandemic, NWS remote capabilities have drastically grown, and previous remote capabilities have improved. **Based on this experience efforts should be made to increase flexibility and utilization of those on telework and to consider, expansion of tertiary backup capabilities (both during the event and post-event), and improvement of service backup processes and criteria.** (See Action 5)

6. Due to COVID restrictions, and the sheer magnitude of the event, conducting post-event storm damage surveys proved difficult or impossible. Several offices leveraged improvements in technology and advancements in the field of emergency management to overcome the inability to conduct in-person surveys. **CRH, in partnership with WFOs, should consider a full evaluation of modern storm survey practices and ways in which event summary information is distributed. In addition,** evaluation of partner information needs, as well as the tools and platforms used to provide that information, is much needed. (See Action 4)

c. Administrative

1. Post-event staff accountability was a concern following the event as major communication disruptions ensued across the impacted area. There was no systematic method for checking on employees after the derecho, and the health and safety of several employees was not determined until several hours after the derecho had passed. **Offices impacted by an event of this scale should use predetermined callback procedures to verify the safety of employees.** (See Action 5)

3. Lessons Learned

Two adjudicators reviewed the WFO AARs to identify potential actions to improve regional forecast operations for similar events and to shed light on best practices for other offices to consider. The Best Practices and Action Items can be found below.

a. Best Practices

i. Utilizing the latest GOES-East satellite (including meso sectors) was crucial in determining the trends and severity of the convection in South Dakota and Nebraska as well as the timing and direction of the storms into Iowa.

ii. Obtaining real-time observations via phone from ASOS and AWOS sites helped heighten messaging in warning statements and social media posts. This, along with rapid dissemination and use of inbound social media content, helped WFOs convey the validity of strong messaging inserted into warning statements and social media posts.

iii. In many cases, WFOs impacted by the derecho developed pre-event warning

strategies to optimize lead time, duration, and polygonology before storms arrived in their CWAs.

iv. New, innovative information tools, such as Twitter Moments and ArcGIS Story Maps, can be utilized to effectively archive and share information with the public, deep relationship core partners, and the media.

v. WFOs should work with media and governmental partners to set expectations on when regular NWS information releases can be anticipated following, at minimum, high-impact events. Outreach efforts should determine if there are any preferred information release times (ex. daily morning updates/releases).

vi. A post-event playbook is highly recommended for each office to make staffing decisions and structure operations for significant post-event workloads. Playbooks should be developed with regional guidance and/or catered to local needs.

vii. The Damage Assessment Toolkit (DAT) can be utilized as an effective coordination/collaboration tool by WFOs to highlight areas of potential damage to between employees in the office, on storm survey teams in the field, those on telework status, and other WFOs (ex. State Liaison Offices, CR ROC).

viii. Effective product/message coordination, especially like what was displayed by WFOs LOT, IWX, and GRR, including upstream information sharing by DVN, should be the standard for what occurs, especially with high-end weather events or those that are difficult to put in one particular product bin.

ix. WFOs with larger aviation needs have found it beneficial to dedicate a meteorologist solely to aviation product updates, TAFs, and aviation partner briefings. While this may not be possible at all WFOs, effective collaboration with onduty CWSU forecasters helps to ensure a consistent IDSS message is presented to aviation partners and decision makers, thus saving money and inconvenience to both airlines and traveling passengers.

x. Some offices employed creative approaches to storm damage surveys. WFO DMX conducted a safety assessment in terms of widespread infrastructure damage/danger as well as COVID, and determined that surveying the widespread swath of wind was nearly impossible to do safely. Rather, DMX chose to conduct “virtual surveys”, which relied on Sentinel satellite imagery and imagery from a wide variety of resources (media, emergency managers, social media). This is an opportunity for the NWS to leverage resources already being deployed to accurately assess the severity of events, especially since emergency management is already conducting their own damage assessments as well. In addition, WFO LOT utilized the Damage Assessment Toolkit (DAT) to input swaths of potential damage based on

data and information coordinated at the WFO that would otherwise be unavailable or hard to collect for storm surveyors.

b. Action Items

i. CR STI will add the WDTD module titled “Advanced Warning Methodology: Winds from Linear Storm Modes” to the CR Regional Training Memorandum for completion by all CR forecasters in FY22.

ii. CR ISD and STI will work with the leaders of the Watch-Warning Gap Testbed to highlight best practices identified during the testbed regarding increased and improved communication with SPC and provide them to all WFOs ahead of the 2022 convective season (and, as available, in 2021).

iii. The CR ROC will explore ways to offer assistance with post-event regional-scale messaging for multiple WFOs following large-scale events.

iv. CR ISD will explore working with the national DAT team to develop color-coded wind damage polygons to better differentiate between estimated wind speed intensity levels.

v. CR will host a regionally supported centralized service backup page housing mission-critical instructions for all forecast offices, CWSUs, and RFCs for timely retrieval. The page will also include links to Continuity of Operations Plans (COOPs) and host instructions on how to activate ENS and/or the local COOP phone tree if a disaster is suspected to have impacted the staff; best practices and alternative staff communication options will also be featured.

vi. CRH will explore the possibility of chartering a Damaging Wind Improvement Project (DWIP) team in order to examine approaches to better anticipate, interpret, warn, and communicate high-end QLCS events.

vii. CR STI will provide WFOs with a list of tools that will enable them to more readily complete timely on-the-fly hodograph adjustments based on available VWP output from local radars.

viii. CR ISD will work with the Services Evolution Team, and possibly WCM sub-regions, to build a Post-Event Playbook template to help offices define roles, manage responsibilities, and coordinate appropriate staffing levels.

5. Appendices (showing each local office AAR)

Below are links to each office's individual AARs:

Omaha

Des Moines

Quad Cities

Chicago & Aurora CWSU

Milwaukee

Central Illinois

Northern Indiana

Grand Rapids